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BIOLOGICAL BULLETIN

THE DEVELOPMENT OF HYDRA.

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Introduction.

The development of hydra has been described by Kleinenberg (4), Kerschner (5), Brauer (3), and a few others, yet there are many points of interest and importance that have not been presented, especially in the origin and formation of the ovary, in fertilization and in early cleavage.

The following results are based mostly upon one species: *Hydra* sp.? (Brauer) or *H. diœcia* (Downing). The three forms *H. viridis, H. grisea and H. fusca* are universally recognized as distinct species. *Hydra* sp.? (Brauer) has been observed by many investigators, yet some prefer to consider it as a variety of *H. fusca*. Brauer at first placed it with *H. fusca*, but upon discovering that the sexes were separate, designated it as *Hydra* sp.?. Downing (2) in his paper on "Spermatogenesis of *Hydra*" uses the name *H. diœcia*.

Hydra sp.? (Brauer) which varies in color from a light to a dark brown, resembles *H. fusca*. When we take into consideration, however, that the sexes are separate, that the eggs are glued to the object on which the parent rests by a secretion from the ectoderm, and that the embryo may hatch out while the egg is still attached to the parent form, it is perhaps justifiable to regard it as a distinct species.

Origin and Formation of the Ovary.

The early formation of the ovary differs from Kleinenberg's account as it is usually given in text-books. The interstitial cells, which divide with nearly the same rate over the body of

the hydra, are about uniform in size, shape and appearance. The formation of the ovary first becomes recognizable by a rapid growth of the interstitial cells in some special region and not by their more rapid division. After these cells have increased several times in volume, they become differentiated into two distinct regions, namely, a more central region, which gives rise to the ovum or ova, and a peripheral region which may be considered the temporary ovary, whose cells cease to enlarge and later contribute directly to the formation of the yolk (Pl. VIII., Fig. 2). The ectodermal cells, with their scanty supply of cytoplasm and nuclei that stain very faintly, are pushed more to the exterior by the enlarged interstitial cells. They often remain connected with the mesoglea by fibrous strands.

The cells of the central region vary in number and their contents contribute directly to the formation of the ovum or ova (Fig. 2, *a*, *b*, *c*). Not merely one but all of these cells continue to enlarge. This increase in size affects the nuclei as well as the cell bodies. The cell walls break down and the cytoplasm which now becomes a common multinucleate mass without any definite outline comes to lie between the enlarged cells of the peripheral region of the ovary and the mesoglea (Fig. 3). The egg at this stage of development as stated above is multinucleate. All of the nuclei enlarge somewhat, the chromatin assumes the spireme condition and the nucleoli are very prominent. One of these nuclei, seldom more than one (Fig. 3, *a*), continues to enlarge and becomes the egg nucleus. The remaining nuclei gradually break down and disappear within the cytoplasm. When two nuclei persist, the cytoplasm becomes separated into two distinct parts. Each part with its contained nucleus becomes a separate egg, which develops independently of the other. The egg does not begin as a single cell, but as a multinucleate mass which results from the fusion of several cells after the breaking down of their walls. Thus, the cytoplasm which originates from several cells becomes the cytoplasm of the egg. Up to this stage of development it is very difficult to determine the exact origin of the sexual organs except from a study of sections. The ovaries and spermaries both begin by a rapid growth of the interstitial cells, but in the formation of the spermary, when the

interstitial cells have increased two or three times in volume, they begin to divide mitotically and give rise to the spermatogonia. In case of the ovary, on the other hand, there is no division of the interstitial cells after they have begun to enlarge.

As the egg nucleus enlarges, the cytoplasm sends out pseudopodial processes (Fig. 4), which form very rapidly and often encircle the entire body of the hydra.

According to Kleinenberg (*H. viridis*), in a zone which surrounds half of the body of the hydra there appear between the neuromuscle cells (ectoderm cells) small tongues of interstitial cells, the nuclei of which are so closely pressed together, that it is hard to distinguish between nucleus and cell body. He furthermore states that by a progressive multiplication of these cells the neuromuscle cells are pushed aside and the tongues of interstitial cells unite with each other, forming a single-layered oblong plate of cells between the ectoderm and endoderm. When the ovary has reached this stage of development, one of the cells, which is situated near the middle of the oblong plate, grows much faster than its neighbors and becomes the egg. The egg cell sends out pseudopodia, which grow very rapidly between the cells of ovary. After the pseudopodia have reached their maximum development they are drawn in, and the egg is completely formed. The cells surrounding the egg break down and act as food for it.

The tongues of interstitial cells which Kleinenberg speaks of are found not only in the region where the ovary begins, but in other parts of the hydra as well. They are especially abundant in hydra that are budding vigorously. The pseudopodia do not grow out between the cells of the ovary, but rather between the ovary as a whole and the mesoglea (Figs. 4 and 6, *ps*).

During the growth of the egg the cytoplasm becomes vacuolated. The nuclear membrane is very indistinct, but the nucleoplasm becomes very dense and granular (Fig. 4, *a*). Several of the degenerating nuclei are still visible in the cytoplasm. In Fig. 5, a stage a little later, they have entirely disappeared. When the egg has reached its growth, it is amœboid in form with the nucleus near the center. The egg at this stage of development contains no yolk (Figs. 4 and 5), but when the pseudopodia are completely formed, the nuclei of the interstitial cells forming the

ovary are taken up by the amœboid egg and become changed into the yolk or pseudo-cells of the egg. Fig. 6 represents a cross-section of several pseudopodia into which the nuclei of the interstitial cells of the ovary are passing. The transformation of these interstitial cells into yolk is shown in Fig. 7, *a–e*. The chromatin becomes very granular and forms a band around the inner border of the nuclear membrane. The nucleolus becomes imbedded in this band of granular chromatin and the nucleus has the appearance of a hollow sphere with its wall thickened on one side. After the yolk or pseudo-cells are formed they divide amitotically.

According to Kleinenberg, the interstitial cells of the ovary surrounding the egg break down and act as food for the developing egg. Brauer says the interstitial cells, after breaking down, enter the egg and give rise to the pseudo-cells.

After the amœboid egg becomes filled with yolk, the pseudopodia are drawn in and the egg becomes nearly spherical (Pl. XI., Fig. 33, *a*), and is surrounded by a single layer of ectodermal cells except at its base. The egg nucleus during the contraction of the pseudopodia becomes very faint and is difficult to recognize. According to Brauer, the nucleus becomes entirely invisible.

Abortive ova are often found in sexually reproducing hydra. They consist of a small mass of yolk cells surrounded by a thin egg membrane, and are devoid of a nucleus. The ovary begins as in the normal cases, but instead of one of the nuclei persisting in the multinucleate cytoplasmic cell mass, they all break down, leaving the common mass of cytoplasm without a nucleus. No pseudopodia are formed. This condition would be represented in Pl. VIII., Fig. 3, if no nuclei were present in the cytoplasm between the enlarged interstitial cells and the mesoglea. Some of the nuclei of the interstitial cells enter the cytoplasm as in the normal egg and form the yolk. The common mass of cytoplasm with its contained yolk now becomes spherical. The abortive ova do not break through the ectoderm, but are gradually absorbed.

Maturation.

Immediately after the pseudopodia are drawn in, the polar bodies are formed (Pl. XI., Fig. 33, *a*, *pb*). When formed they

remain attached to the egg by means of a cytoplasmic thread and are found partly imbedded in the egg membrane beneath the ectoderm surrounding the egg. When maturation is completed an opening breaks through the ectoderm in the region of the polar bodies. The egg with its contained yolk is very plastic, and as the ectoderm contracts or is drawn back, the egg contents is gradually forced through the small opening in the ectoderm. It requires from one to three minutes for the contents of the egg to pass through the opening of the ectoderm. The different changes which the egg undergoes in this process are shown in Pl. X., Figs. 27–32. The egg now becomes situated in a basin-like cavity of the ectoderm and is entirely free except for a small portion at the vegetative pole (Figs. 31 and 32), where it is finally attached to the cup-shaped ectoderm by means of transparent pseudopodial processes of the egg membrane, which pass into the ectoderm. An adhesive substance which is secreted by the ectoderm also aids in their attachment. The egg membrane is very tough and firm, and remains distinct during cleavage.

The polar bodies after the egg passes to the exterior become free in the water (Pl. VIII., Fig. 1). They are more distinctly shown in Pl. IX., Fig. 8, *pb*, with their connecting thread of cytoplasm. The chromosomes of the polar bodies do not become a homogeneous mass but retain their individuality. The first polar body is larger than the second. The connecting thread of cytoplasm becomes finer and longer, until it breaks loose from the egg and leaves the polar bodies free in the water, where they almost immediately go to pieces. Their connection with the egg may persist until after the third cleavage, as shown in Pl. XI., Figs. 36, 42.

According to Brauer's account, the polar bodies disappear before cleavage begins. I was unable to distinguish any movement of granular substance through the connecting thread between the polar bodies and the egg, but, as the granular cytoplasm of the strand is similar to that of the egg, it is highly probable that such a flow of substance occurs.

FERTILIZATION.

Normally fertilization occurs within two hours after the egg becomes free in the water. There is a small cavity formed at the

point where the sperm enters the egg (Brauer). The egg becomes surrounded by a number of sperm, several of which may pass into the egg membrane, but only one enters the egg. It is interesting to note that the egg may remain susceptible to the sperm twenty-four hours after it passes through the ectoderm, but if the sperm are not added within twenty-four to thirty hours after maturation or the passing of the egg to the exterior, fertilization will not take place.

Two lots of hydras with eggs, one twenty-four hours and the other immediately after maturation, were placed in separate vessels containing water and sperm added. Fertilization occurred in both instances within two hours. The rate of cleavage was similar in both cases. In the unfertilized eggs, the yolk spheres cease dividing, gradually break down and the egg becomes a hollow membranous sphere containing a fluid substance.

Almost immediately after fertilization the peripheral cytoplasm becomes free from yolk and is more finely granular than the cytoplasm within the egg.

The entrance of the sperm and union of male and female pronuclei agree with Brauer's account. After the union of the pronuclei the cleavage nucleus passes a short distance into the egg from the animal pole and divides (Pl. IX., Fig. 9).

Cleavage.

The cleavage of *Hydra* sp.? is total, unequal and regular. Brauer states that the cleavage is equal and total, but he gives no figures to show the early cleavage stages. Kleinenberg says the cleavage (*H. viridis*) takes place in a remarkable manner and that pseudopodia or cleavage papillæ are formed at the point where the first cleavage begins. He also describes the second cleavage as very erratic, and states that the egg undergoes peculiar changes during cleavage.

The cleavage of *Hydra* sp. ? does not exhibit such erratic conditions as Kleinenberg describes for *H. viridis*.

Just before the first cleavage the egg changes from a spherical to a more oblong form, and the cleavage passes through the short axis. This peculiarity is true only of the first, second and third cleavages, being especially well marked in the first and second.

The first cleavage begins at the animal pole. The eggs of *Hydra* sp.? do not show any blunt projections or cleavage papillæ, as Kleinenberg and Andrews describe in *Hydra viridis*. As the first cleavage furrow deepens, pseudopodia are formed, which project into the cleavage furrow (Pl. XI., Fig. 34). These pseudopodial projections change in shape by contraction or expansion as the cleavage furrow progresses from one side to the other. The pseudopodia of one side may fuse with those of the opposite. When this occurs, they do not pull apart but remain connected during cleavage. Those that do not fuse are soon drawn in. The living material shows a movement of the granular cytoplasm containing a few yolk spheres from one blastomere to another through these connections. New pseudopodia continue to form until the cleavage furrow reaches the opposite side. When the cleavage is nearly complete the furrow closes at the point where it first began (Fig. 35), and when completely closed the pseudopodial connections are no longer visible in the living egg. The bottom of the cleavage furrow shows a distinct opening which extends entirely through the egg laterally and progresses with the cleavage from the animal to the vegetative pole (Fig. 35). This interesting phenomenon was observed by Kleinenberg and Andrews in *H. viridis*, especially during the first cleavage. Fig. 36 represents the first cleavage completed and the relation of the egg to the ectoderm as it appears in the living hydra. Sections of the different stages of the first cleavage are shown in Pl. IX., Figs. 9–11. After the first cleavage is completed, the nuclei divide before the second cleavage begins (Fig. 11). Brauer states that the second cleavage begins before the first is completed.

The second cleavage passes through a plane at right angles to the first and is nearly equal. This cleavage is similar to the first, as shown in Pl. XI., Figs. 37 and 38. A polar view of the second cleavage is shown in Fig. 39. A section of the four-cell stage taken at right angles to the polar axis (Pl. IX., Fig. 12) shows a number of pseudopodial connections or bridges persisting. The third cleavage differs from the first and second in that no pseudopodia are formed in the cleavage furrow. Pl. XI., Figs. 40–42 represent the different stages of the third cleavage as it appears

from side view in the living material. The third cleavage furrow which passes entirely through the egg instead of becoming obliterated within, as in the first and second cleavages, becomes the cleavage cavity. Pl. IX., Fig. 13 represents a section passing through the poles of the egg shortly after the third cleavage is complete. The cleavage cavity is very distinct and shows the nuclei near the inner ends of the cells. The egg now becomes more spherical and the inner ends of the cells become rounded off. The blastomeres of the vegetative pole are larger than those of the animal pole. The fourth and fifth cleavages are parallel to the third, but there is some irregularity in their time of formation. Both cleavages may begin at the same time, but in most instances observed the cells above the equator divided first. They differ from the first, second and third cleavages in that the cleavage does not start at one side and gradually pass to the opposite, but instead begins at different points on the surface at the same time. The cleavage furrows are very indistinct. Pl. X., Fig. 14 represents the fourth and fifth cleavages completed, as they appear in a plane passing through the poles. The cleavage cavity is very irregular and increases considerably in size (Pl. IX., Fig. 15) without any further division of the cleavage cells. This peculiarity is due to a change in the form of the cells, whereby their long axis becomes really tangential. The cleavage cells now divide very rapidly and it is impossible to distinguish any further regularity in the process of cleavage (Fig. 16).

Origin of Endoderm.

When the cleavage cavity reaches its maximum growth, the embryo consists of a large spherical blastula with its single layer of primitive ectodermal cells, which have about the same thickness throughout; but some of them now begin to enlarge, so that they come to project into the cleavage cavity (Pl. X., Fig. 17), and instead of dividing parallel to the surface begin to divide at right angles to it. The inner ends of the divided cells become free in the cleavage cavity and give rise to the endoderm. A section passing through the equatorial plane (Pl. IX., Fig. 18) shows the cells not only dividing radially but also tangentially. This process continues until the cleavage cavity becomes filled with cells

(Fig. 19). The cells within the cleavage cavity also divide very rapidly (Pl. X., Fig. 20), and the embryo becomes a solid spherical mass of cells with the cleavage cavity entirely obliterated.

The formation of the endoderm begins uniformily at the different poles of the blastula. Its origin is multipolar as Brauer states. According to Brauer, during the formation of the endoderm some of the cells which divide radially and remain within the wall of the blastula force the primitive ectodermal cells, which have a narrow base, from the periphery into the cleavage cavity before they divide, and thus an entire cell of the primitive ectoderm becomes an endodermal cell. The species studied showed a number of cells dividing radially in the periphery during the formation of the endoderm, but I was unable to find any indication that entire cells were forced from the periphery into the cleavage cavity.

According to Kerschner (5) and Korotneff (6), the endoderm is formed by the inwandering of cells from the vegetative pole of the egg.

When the endoderm is completely formed division ceases and the endodermal cells with their abundance of yolk can readily be distinguished from the cells of the outer layer or ectoderm.

Egg Membranes.

The outer and inner egg membranes are formed from the ectodermal cells. The outer membrane begins as an outgrowth from the different cells of the ectoderm. A very small portion or nearly all of an ectodermal cell may take part in this process (Pl. X., Figs. 20–22). These outgrowths in the early formation of the membrane remain continuous with the cell from which they originate, and are often nearly as large as the body of the cell itself (Fig. 23, *o*). The outer protoplasmic ends of these projections assume various shapes (Fig. 25). The thin elastic wall surrounding these outgrowths, which is a continuation of the wall of the ectodermal cell, often becomes very delicate, breaks through and allows the cytoplasm of the cell to flow out, thus causing the cell to collapse. The different outgrowths now fuse at their basal ends and form a continuous membrane around the developing embryo (Fig. 25). This membrane becomes very tough and has

the nature of chitin. When it is nearly formed, a second or inner membrane begins as a secretion from the ectodermal cells over the entire embryo just beneath the outer egg membrane (Figs. 25 and 26).

According to Kleinenberg, the entire primitive ectoderm is used in the formation of the outer and inner membranes. The formation of these membranes in *Hydra* sp.? confirms Brauer's account in that the inner ends of the ectodermal cells persist and become the definitive ectoderm.

After the membranes are formed, the eggs are glued to the object on which the parent rests. This, however, is not always true. In a few instances observed, the embryo hatched out while the eggs were yet attached to the parent. Brauer states that the eggs are glued by a sticky secretion from the ectoderm to the object on which the parent rests, and that the parent remains in contact with the egg until the embryo hatches out.

The formation of the interstitial cells and of the body cavity was not studied. The embryo hatches out in from eight to ten days after the outer and inner membranes are formed.

General Remarks.

The condition necessary for the appearance of sexual organs in hydra has long been a question of much interest, especially among scientific investigators. Various chemical solutions as well as different conditions of food and temperature have been tried with little or no success.

Downing (2) by subjecting hydra to various degrees of reduced temperature was able to get hydra to produce sexual organs after an exposure in a dark refrigerator to a temperature of about 12° C. for twelve hours. But as sexual organs appeared at the same time on several control hydras in the laboratory which were kept in the light at the temperature of the room, he concluded that light and temperature are not controlling factors in determining the appearance of sexual organs.

During the three different years that Hydra sp.? were collected at intervals from two to three times a week, no sexual organs were found, but buds were abundant in the winter season as well as during the warmer months. From this I was led to infer that

in this particular locality conditions were antagonistic to the development of sexual organs, but favorable for budding. After the hydras were brought into the laboratory and put in aquaria with abundance of food and the water kept well aërated, they reproduced by budding more rapidly than out of doors. As many as four and sometimes five buds were found on the same individual. After the hydras continued to bud very vigorously from two to six weeks, ovaries and spermaries were produced. Buds and ovaries or spermaries are often contemporaneous on the same individual. Sexual organs were never found on the buds. But if the buds after becoming mature were supplied with plenty of food, they in turn would produce sexual organs after passing through a stage of vigorous budding, as described above. The time for the appearance of the sexual organs on different individuals varied with the rate of budding.

According to Downing when buds and spermaries were found on the same individual, the spermaries appeared on the vigorous bud.

The hydra in most instances continued to feed during sexual reproduction. The endodermal cells at the time of the first formation of the sexual organs are gorged with food and protoplasmic granules, while the ectodermal cells are less granular and begin to show vacuoles. During the early formation of the sexual organs the endodermal cells, especially in the region of the sexual organs, become less granular and are almost free from food granules. This condition is most striking while the pseudopodia of the egg are forming. The pseudopodia grow so rapidly that the digestive process can not keep pace. But when the pseudopodia are completely drawn in, the endodermal cells immediately ingest food and show their former granular condition. But in those hydras that cease feeding during the sexual period, the endodermal cells remain non-granular and large vacuoles appear. The size of the egg in *Hydra* sp.? varies considerably with the amount of food present. This condition indicates a rapid use of the nutritive material during the development of the ovum.

Hydras that were kept in aquaria in a starved condition never produced sexual organs and very seldom budded. The ecto-

dermal and endodermal cells were similar to those in hydra during the formation of the sexual organs. This would indicate that lack of food and production of sexual organs give similar effects. Sexual organs never appeared on well-fed hydras, except those that had passed through a vigorous process of budding for a definite time. This indicates very forcibly that food is not a direct controlling factor in the production of sexual organs, but instead favors vigorous budding, which in turn gives rise to conditions that cause the appearance of these organs in the animal's life history. The question immediately arises, what are these conditions? Is it some inherent factor within the interstitial cell that has to do with the appearance of the sexual organs irrespective of food, temperature, etc.; or is it perhaps the inability of the cells in general to assimilate the food present after an active process of budding which leads to the differentiation of sexual organs in some definite region so that a new cycle may be started? The latter view seems the more plausible, as the ectodermal cells do pass through a marked change in those hydras that have been budding actively for some time. The cells become less granular, numerous vacuoles appear, the nuclei stain less intensely and very seldom divide. These conditions, however, vary in different parts of the same hydra. Moreover, as the ectodermal cells show this somewhat degenerate or exhausted condition in the parent hydra that is actively feeding and budding, it suggests very forcibly, as stated above, the inability of the ectodermal cells to assimilate the food present.

Summary.

The interstitial cells which give rise to the ovary, after increasing in volume become differentiated into two distinct regions: a central region which contributes directly to the formation and growth of the ovum, and a peripheral region whose nuclei later enter the egg and become changed into yolk.

Occasionally two nuclei persist in the central region and give rise to two distinct ova. Each ovum has its individual membrane and is entirely independent of the other. The ova are forced through the small opening of the ectoderm to the exterior by the contraction or pulling back of the ectoderm. The polar bodies

remain attached to the egg until after the third cleavage by means of a connecting thread of cytoplasm. When the eggs are not fertilized they disintegrate and finally fall to pieces.

The cleavage is total, unequal and regular. The cleavage cells communicate with each other by means of protoplasmic bridges or connections. There is a passage of substance from one cleavage cell to the other. The cleavage cavity begins with the third cleavage. The blastula when completely formed is a hollow sphere of primitive ectodermal cells.

The origin of the endoderm is multipolar. The outer and inner egg membranes are formed from the ectoderm ; the first is formed by an outgrowth of the ectodermal cells, the second by means of a secretion from the same cells. The inner ends of the ectodermal cells persist and become the definitive ectoderm. The gastrula consists of a solid spherical mass of cells surrounded by the egg membranes. The eggs are either glued to the object on which the parent rests or remain attached to the parent until the embryo hatches. The eggs of *Hydra* sp. ? will not continue to develop when removed from the parent after fertilization occurs, or even after cleavage has begun.

Hydras seldom continue to reproduce by budding after the sexual generation is completed. Exhaustion due to vigorous budding precedes the appearance of the sexual organs, more especially the ovaries.

Hydra sp. ? reproduces by budding during the entire year. No sexual organs were found on the hydras when collected, but after the animals had been kept in aquaria with abundance of food, sexual organs appeared on those hydras that had been budding vigorously for several weeks. Spermaries or ovaries never appeared on buds.

It gives me pleasure to express my gratitude to Dr. George Lefevre for reading this manuscript.

Zoölogical Laboratory,
University of Missouri,
January 30, 1908.

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EXPLANATION OF PLATE VIII.

FIG. 1. Egg with polar bodies, immediately after it has passed to the exterior of the ectoderm. *c.m.*, egg membrane.

FIG. 2. Section showing early formation of ovary at the time the interstitial cells become differentiated into two distinct regions; *a*, *b*, and *c*, cells of the central region that are directly concerned in the formation of the ovum or ova; *p.r*, cells of the peripheral region which contribute to the formation of the yolk. $\times$ 76.

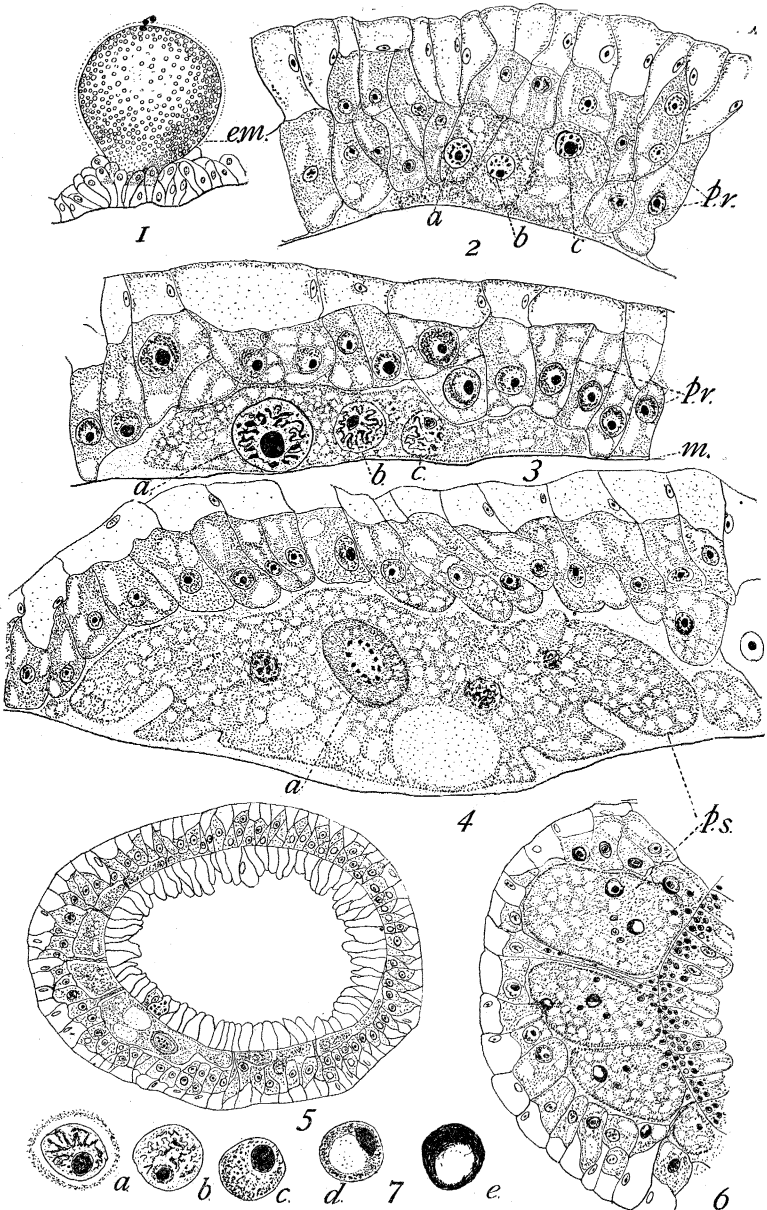
FIG. 3. Section, little later than preceding, showing the ovum between the interstitial cells, which later become the yolk, and the mesoglea; *a*, nucleus, which becomes the egg nucleus; *b.c*, nuclei breaking down within the egg cytoplasm; *m*, mesoglea.

FIG. 4. Section of ovum showing the formation of the pseudopodia; *a*, egg nucleus; *p.s*, pseudopodia. $\times$ 80.

FIG. 5. Cross-section of ovary, little later than preceding, just before the formation of the yolk or pseudo-cells.

FIG. 6. Cross-section of several pseudopodia showing the entrance of nuclei of the interstitial cells of ovary, which become the yolk.

FIG. 7. *a–e*, five stages in the transformation of interstitial nuclei into yolk.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Explanation of Plate IX.

Fig. 8. Section through the animal pole of egg showing polar bodies with connective thread of protoplasm; *p.b*, polar bodies; *pr.n*, pro-nucleus; *e.m*, egg membrane. × 750.

Figs. 9 and 10. Sections of eggs passing through poles, showing first cleavage and protoplasmic connections between cleavage cells: *p.c*, protoplasmic connections.

Fig. 11. First cleavage completed, and division of nuclei for second cleavage. × 55.

Fig. 12. Section of egg at right angles to polar axis, showing second cleavage complete. × 58.

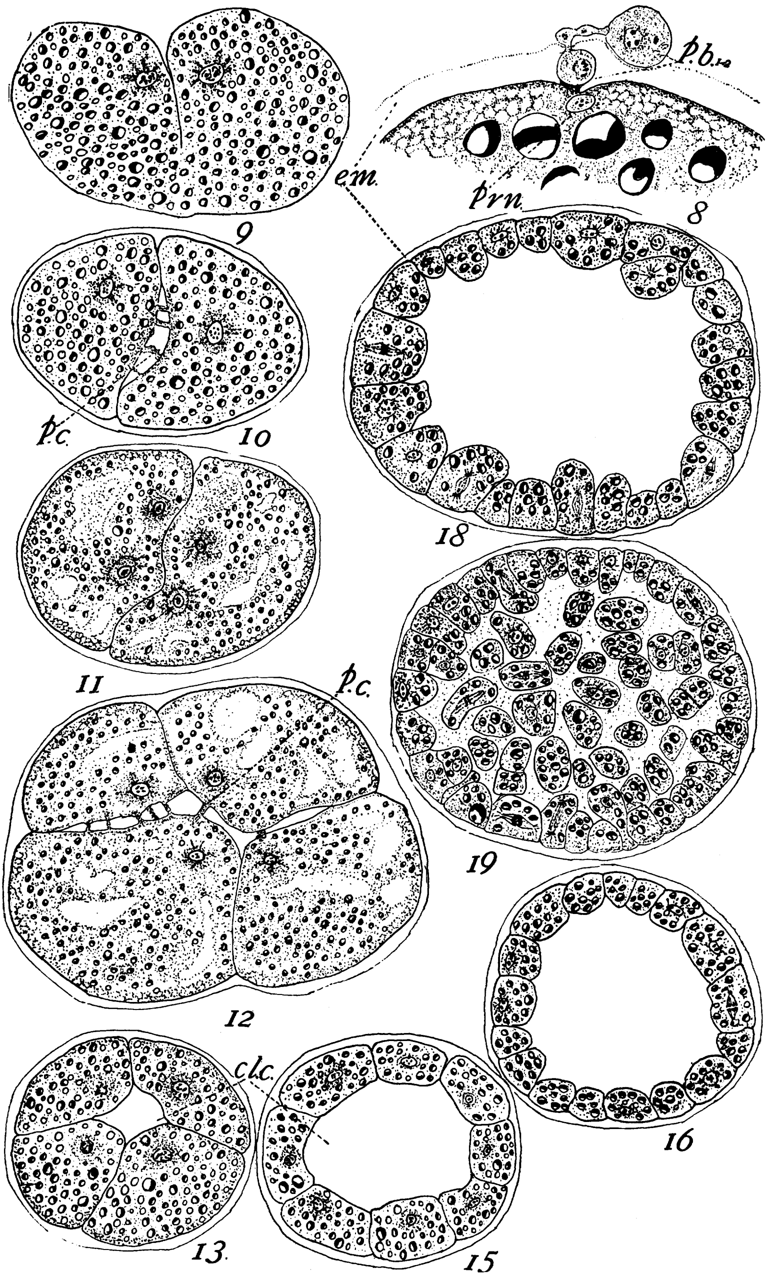
Fig. 13. Section of egg passing through poles with third cleavage completed and beginning of cleavage cavity; *cl.c*, cleavage cavity.

Fig. 15. Fourth and fifth cleavages complete. Cleavage cells becoming flattened out around the cleavage cavity.

Fig. 16. Stage a little later than preceding.

Fig. 18. Maximum development of cleavage cavity; primitive ectoderm cells dividing to form endoderm.

Fig. 19. Cleavage cavity becoming filled with endodermal cells.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Explanation of Plate X.

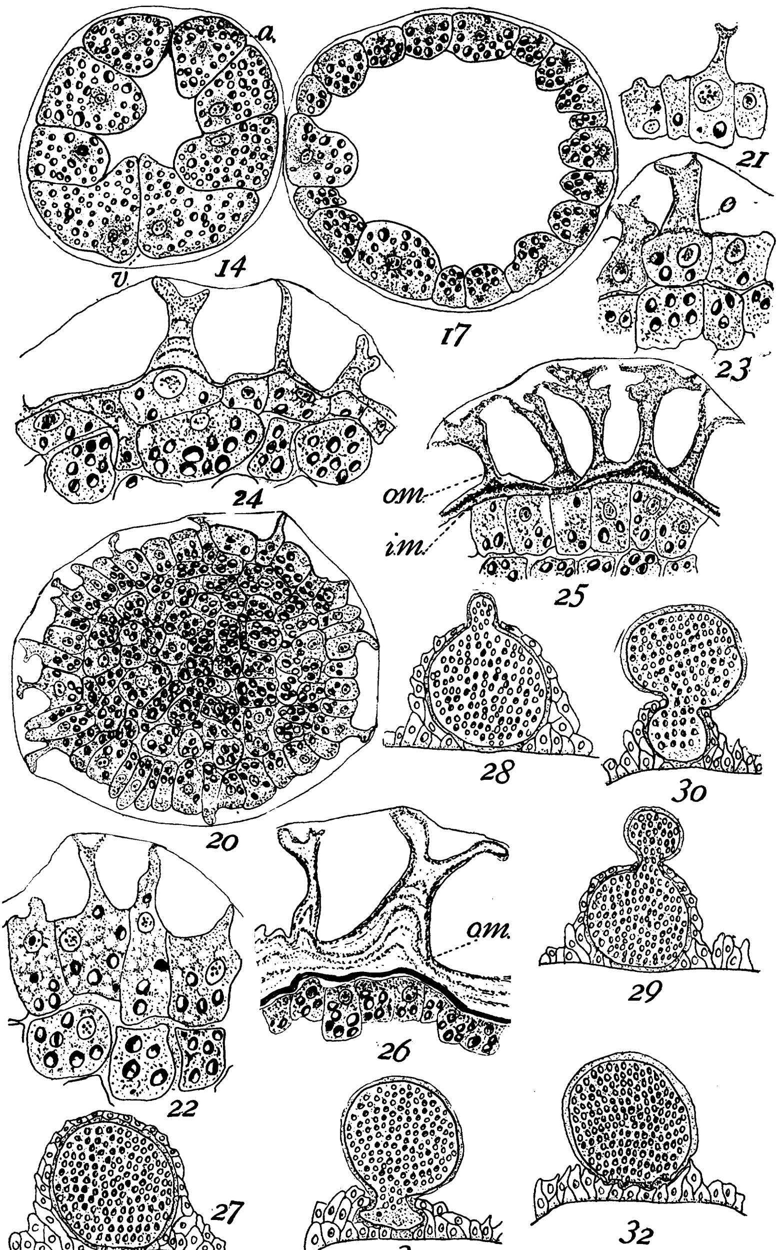
FIG. 14. Fourth and fifth cleavages completed; *a*, animal; *v*, vegetative pole.

FIG. 17. Blastula with primitive ectoderm cells, just before the formation of the endoderm.

FIG. 20. Cleavage cavity completely filled with endoderm cells and the beginning of the outer egg membrane.

FIGS. 21–26. Formation of the outer and inner egg membranes; *o*, outgrowths.

FIGS. 27–32. Different shapes which the egg assumes in passing to the exterior of the ectoderm.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Explanation of Plate XI.

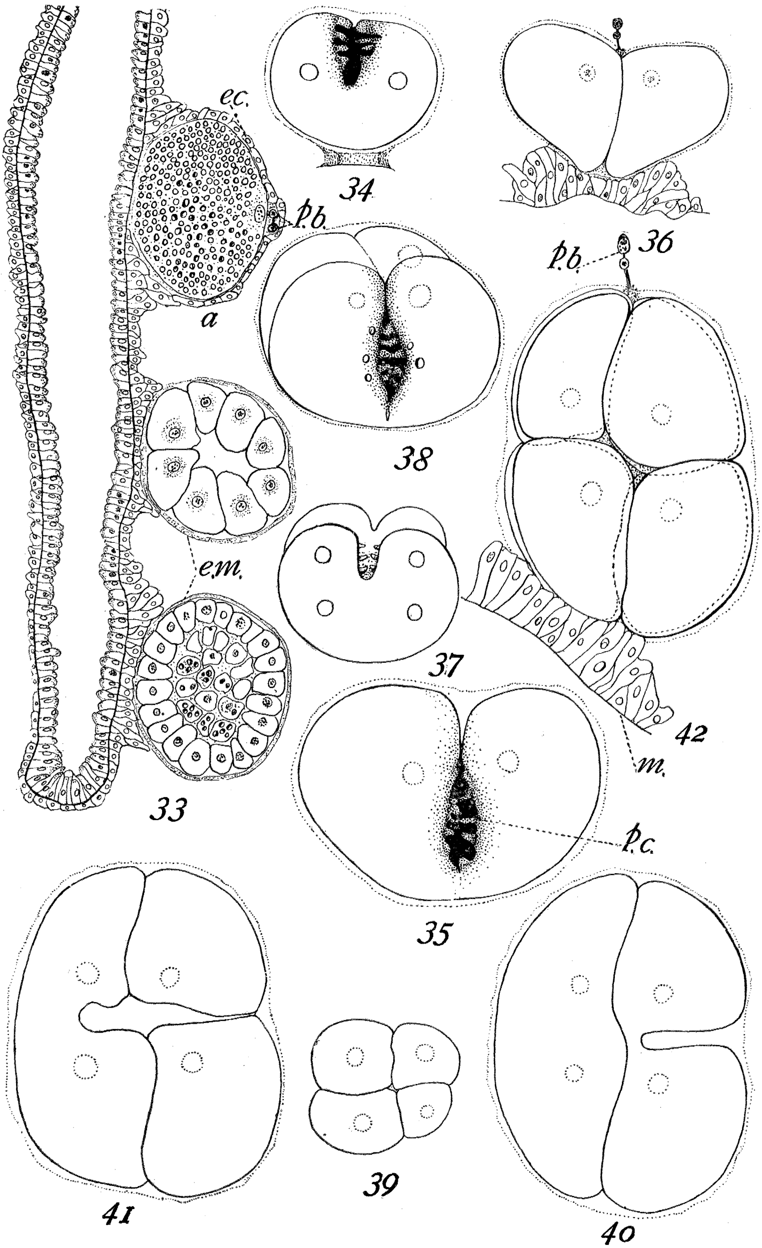
FIG. 33. Longitudinal section of aboral end of hydra, showing eggs in different stages of development; *e.c*, ectoderm surrounding egg; *p.b*, polar bodies; *prn*, pronucleus; *e.m*, egg membrane.

FIGS. 34–36. Surface views of living eggs, showing first cleavage; side view; *p.c*, protoplasmic connections; *p.b*, polar bodies.

FIGS. 37 and 38. Second cleavage, side view.

FIG. 39. Polar view of second cleavage.

FIGS. 40–42. Third cleavage of living egg; side view; *p.b*, polar bodies.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